

REMARKS

Claims 1-9, 11-14, 16-19 and 21-30 are pending in this application. Claims 1, 4, 14 and 17 have been amended. No new matter has been introduced.

Claim 4 is objected to under 37 CFR 1.75 (c) as being of improper dependent form for failing to further limit the subject matter of a previous claim. Claim 4 has been amended to recite that the step of "forming said at least one opening further comprises patterning said methylsilsequiazane layer with a mask."

Claims 1-9, 16-19, 21-24, 29 and 30 are rejected under 35 U.S.C. §103(a) as being unpatentable over Huang et al. (U.S. Patent No. 6,313,028) ("Huang") and Applicant's Admitted Prior Art ("APA"). This rejection is respectfully traversed.

The claimed invention relates to a method of forming a copper damascene structure. As such, amended independent claim 1 recites a "method of forming a copper damascene structure" by *inter alia* "providing a metal layer within a semiconductor substrate," "forming a low-dielectric constant layer over and in contact with said metal layer" and "directly patterning said low-dielectric constant layer to form at least one opening through said low-dielectric constant layer, said opening extending to at least a portion of said metal layer." Amended independent claim 1 also recites "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions" and "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing." Amended independent claim 1 further recites "subsequently providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition."

Amended independent claim 17 recites a method of forming a copper damascene structure by *inter alia* "forming a material layer of methylsilsequiazane over a substrate," "forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetra-methyl-ammonium hydroxide solution" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening." Amended independent claim 17 also recites "removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer" and "subsequently providing a copper layer in said at least one opening."

Huang relates to a method of fabricating a dual damascene. Huang teaches that "[a] dielectric layer is formed on a substrate" and "[a] diffusion barrier layer is formed on the dielectric layer," so that "[a] portion of the diffusion barrier layer and the dielectric layer is removed to form a trench and a via hole." (Abstract). Huang also teaches that "[a] barrier layer is formed on the diffusion barrier layer and in the trench and the via hole." (Abstract). Once the barrier layer on the diffusion barrier layer is removed by chemical-mechanical polishing, "[a] conductive layer is formed in the trench and the via hole by selective deposition." (Abstract).

The subject matter of claims 1-9, 16-19, 21-24, 29 and 30 would not have been obvious over Huang in view of the APA. Specifically, the Office Action fails to establish a *prima facie* case of obviousness. Courts have generally recognized that a showing of a *prima facie* case of obviousness necessitates three requirements: (i) some suggestion or motivation, either in the references themselves or in the knowledge of a person of ordinary skill in the art, to modify the reference or combine the reference teachings; (ii) a reasonable expectation of success; and (iii) the prior art references must teach or suggest all claim limitations. See e.g., In re Dembiczak, 175 F.3d 994 (Fed. Cir.

1999); In re Rouffet, 149 F.3d 1350, 1355 (Fed. Cir. 1998); Pro-Mold & Tool Co. v. Great Lakes Plastics, Inc., 75 F.3d 1568, 1573 (Fed. Cir. 1996).

In the present case, Huang and the APA, whether considered alone or in combination, fail to disclose, teach or suggest all limitations of amended independent claims 1 and 17. Huang does not disclose, teach or suggest “*providing a metal layer within a semiconductor substrate,*” “*forming a low-dielectric constant layer over and in contact with said metal layer*” and “*directly patterning said low-dielectric constant layer to form at least one opening through said low-dielectric constant layer, said opening extending to at least a portion of said metal layer,*” as amended independent claim 1 recites. Huang teaches the formation of conductive layer 202, which would arguably correspond to the “metal layer” of the claimed invention, within the substrate 200. (Col. 3, lines 4-6). Huang also teaches the formation of the dielectric layer 206, which would arguably correspond to the “low-dielectric constant layer” of the claimed invention, over the substrate 200. (Col. 3, lines 6-8). However, in Huang, dielectric layer 206 is not formed “over and in contact with” the conductive layer 202. Rather, in Huang, a cap layer 204 is formed between the conductive layer 202 and the dielectric layer 206.

Huang is also silent about “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” or about “subsequently providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition,” as amended independent claim 1 recites. Huang teaches that conformal barrier layer 212, which would arguably correspond to the “tungsten nitride layer” of the claimed invention, could be formed of tungsten nitride material. However, Huang does not disclose, teach or suggest “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions,” as in the claimed invention.

In addition, Huang is silent about “providing a copper layer in said at least one opening and in contact with said tungsten nitride layer,” as amended independent claim 1 recites. Huang specifically emphasizes that “[i]n a case where a material of the conductive layer 214 is copper, the material of the barrier layer 212 is preferably Ta/TaN.” (Col. 4, lines 5-7). This is because, as Huang explains, “[d]uring the selective chemical vapor deposition of the copper conductive layer 214, the Ta/TaN barrier layer 212 serves as an activation center for selective chemical vapor deposition.” (Col. 4, lines 11-14). Thus, Huang clearly teaches that, when copper is selected as the material for the conductive layer 214, a Ta/TaN barrier layer is employed and not a “tungsten nitride layer,” much less a “tungsten nitride layer by atomic-layer deposition using sequential surface reactions,” as in the claimed invention.

Huang also fails to disclose, teach or suggest all limitations of amended independent claim 17. Huang is silent about “forming a material layer of methylsilsequiazane over a substrate,” much less about “forming at least one opening through said methylsilsequiazane layer by etching said methylsilsequiazane layer with a tetra-methyl-ammonium hydroxide solution,” as in the claimed invention. Huang teaches that dielectric layer 206 “is preferably a silicon oxide layer formed by plasma-enhanced chemical vapor deposition (PECVD), or spin-on polymer (SOP) with a low dielectric constant” (col. 3, lines 23-26), and not a “methylsilsequiazane layer,” as in the claimed invention.

As noted above, Huang also fails to teach or suggest “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” or “removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer,” as amended independent claim 17 recites. In Huang, diffusion barrier layer 207 is formed over the dielectric layer 206. Thus, subsequent to the trench and via formation, barrier layer 212 of Huang is

formed over and in contact with the diffusion barrier layer 207, and not “above and in contact with a top surface of said methylsilsequiazane layer,” as in the claimed invention.

The APA also fails to teach or suggest all limitations of amended independent claims 1 and 17. The APA does not teach or suggest a “method of forming a copper damascene structure” by *inter alia* “directly patterning said low-dielectric constant layer to form at least one opening,” “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing,” as amended independent claim 1 recites. The APA also fails to disclose, teach or suggest all limitations of amended independent claim 17.

Applicants also note that the combination of Huang with the APA fails to disclose, teach or suggest all limitations of amended independent claims 1 and 17. For example, none of Huang and the APA, whether considered alone or in combination, discloses, teaches or suggests “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions” and “removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing” (claim 1) or “forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening” and “removing horizontal portions of said tungsten nitride layer formed above and in contact with a top surface of said methylsilsequiazane layer” (claim 17). For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 1-9, 16-19, 21-24, 29 and 30 is respectfully requested.

Claims 14 and 28 are rejected under 35 U.S.C. §103(a) as being unpatentable over Huang in view of the APA and Shachan-Diamand et al. This rejection is respectfully traversed.

As noted, the claimed invention relates to a method of forming a copper damascene structure. As such, amended independent claim 14 recites a "method of forming a copper damascene structure" by *inter alia* "directly patterning a low-dielectric constant layer with a mask to form at least one opening through said low-dielectric constant layer," "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening, said tungsten nitride layer being formed above and in contact with a top surface of said low-dielectric constant layer" and "removing horizontal portions of said tungsten nitride layer formed above and in contact with said top surface of said low-dielectric constant layer by chemical mechanical polishing." Amended independent claim 14 also recites "subsequently providing a copper layer in said at least one opening, wherein said copper layer is formed by contact displacement copper deposition at room temperature."

None of Huang, the APA and Shachan-Diamand et al., whether considered alone or in combination, discloses, teaches or suggests all limitations of amended independent claim 14. Huang does not disclose, teach or suggest "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions." As noted above, although Huang mentions tungsten nitride as one of the materials for the formation of barrier layer 212, Huang is silent about "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions."

Huang also fails to teach or suggest that the tungsten nitride layer is "being formed above and in contact with a top surface of said low-dielectric constant layer," as

amended independent claim 14 recites. In Huang, diffusion barrier layer 207 is formed over the dielectric layer 206. (Col. 3, lines 6-8). Thus, subsequent to the trench and via formation, barrier layer 212 of Huang is formed over and in contact with the diffusion barrier layer 207, and not "above and in contact with a top surface of said low-dielectric constant layer," as in the claimed invention. Applicants also submit that the APA and Shachan-Diamand et al. do not disclose, teach or suggest all limitations of amended independent claim 14.

Further, the combination of Huang, the APA and Shachan-Diamand et al. does not disclose, teach or suggest all limitations of the claimed invention. For example, none of Huang, the APA and Shachan-Diamand et al., whether considered alone or in combination, discloses, teaches or suggests "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening, said tungsten nitride layer being formed above and in contact with a top surface of said low-dielectric constant layer" and "removing horizontal portions of said tungsten nitride layer formed above and in contact with said top surface of said low-dielectric constant layer by chemical mechanical polishing," as amended independent claim 14 recites. Accordingly, the Office Action fails again to establish a *prima facie* case of obviousness. Withdrawal of the rejection of claims 14 and 28 is also respectfully requested.

Claims 11-13 and 25-27 are rejected under 35 U.S.C. §103(a) as being unpatentable over Huang in view of APA and further in view of Kaloyeros. This rejection is respectfully traversed.

As noted above, Huang and the APA, whether considered alone or in combination, fail to teach each and every limitation of amended independent claims 1 and 17. Kaloyeros, alone or in combination with Huang and the APA, also fails to

disclose, teach or suggest all limitations of these claims. For at least these reasons, Applicants submit that claims 11-13 and 25-27 are allowable.

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to pass this application to issue.

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Respectfully submitted,

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